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CT Evaluation of Chamberlain's and Mcrae's Lines and its Significance in Relation to Skull Base Problems at Meenakshi Medical College and Hospital

Gnanavel A.[1], Maheswari K.[2], Lalitha R.[3], Rajasekar[4]

Abstract

Introduction: The odontoid process is the central pillar of craniovertebraljunction. It is assessed by lateral cervical spine and base of skull radiographs which however have diagnostic challenges due to the complexity of the anatomy. Modern-day Computed Tomography (CT) offers excellent bony detail and its ability to reconstruct the acquired CT data into various imaging planes makes the assessment of the cranio-cervical junction easy and more accurate. The standard skull base lines (Chamberlain's and McRae's lines) are used in the evaluation of the craniovertebral junction. They help to illustrate the degree of deformity in patients with basilar impression and aid in surgical decisions with regard to decompression, fixation and stabilization. These measurements are also used as guides in the conservative follow up of patients or those who are surgically managed. *The Aim of The Study:* To evaluate the relationship of the odontoid tip of C2 to the standard skull baselines of Chamberlain's and McRae's on computed tomography in symptomatic and asymptomatic patients. *Materials and Methods*: Reformatted midline sagittal CT images of 150 patients (M-68,F-82) were retrospectively evaluated. The shortest perpendicular distance was measured from the Chamberlain's and McRae's baselines for each subject to the odontoid tip. *Results:* The most common age group in male is 41-50 and female 31-40 years. The mean position of the odontoid process was 2.65 mm below Chamberlain's line (median 2.7 mm, SD 0.21mm) and 4.6 mm (median 4.6 mm, SD 0.19 mm) below McRae's line.There was no statistically significant difference in measurements between male and female patients. *Conclusion*: Imaging of this small structure to reach a specific diagnosis continues to be a challenge for radiologists. Multiplanar imaging with CT allows more detailed evaluation of bony and soft tissue structures. Adequate knowledge of development, complex anatomy, various disease processes, topographic relationships of odontoid with respect to CVJ and craniometry in association with the appropriate clinical background can provide a meaningful diagnosis. These results provide the mean of normal distance from the odontoid process to the standard skull base lines on CT. This study can be used as a base line data to access skull base problems.

Keywords: Reformatted Midline Sagittal CT; Chamberlain's; McRae's Lines; Odontoid Process.

Introduction

The craniocervical junction consists of the bone that forms the base of the skull (occipital bone) and the first two bones in the spine, the atlas and axis. Disorders that affect theforamen magnum are a particular concern because important structures pass through this opening. The following structures in the foramen magnum are lower end of medulla oblongata and the meninges, vertebral vessels surrounded by sympathetic plexus of nerves, spinal root of accessory nerve, anterior and posterior spinal arteries and occasionally tonsil of cerebellum on either side of brain stem. Disorders that put pressure on the lower parts of the brainstem, upper part of the spinal cord or nearby neurovascular structuresand malalignment of the first and second spinal bones (atlantoaxial subluxation or dislocation) result in paralysis, weakness, difficulty sensing vibration, pain, temperature, dizziness, and impaired vision [1]. Anatomical evaluation of the craniocervical junction has improved significantly since the advent of multiplanarcomputerized tomography (CT). The capability to reconstruct transverse cuts into axial, sagittal, coronal and oblique reformats has enhanced

Author's Affiliation: [1,3]Assistant Professor [2]Professor and Head [4]Professor, Department of Anatomy, Meenakshi Medical College Hospital & Research Institute, Kancheepuram, Tamil Nadu 631552, India.

Corresponding Author: Gnanavel Anbalagan, Assistant Professor, Department of Anatomy, Meenakshi Medical College Hospital & Research Institute, Kancheepuram, Tamil Nadu 631552, India.
E-mail: dragnanavel@gmail.com

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ability to assess craniocervical junction deformities. CT imaging also allows accurate measurements of classical lines and angles, transverse and AP diameters of the foramen magnum and spinal canal. The odontoid process is a part of the C2 or axis vertebra and forms the pivot of the structures forming the craniovertebral junction (CVJ). The pathologies of odontoid can be congenital or acquired. Congenital anomalies include various types of odontoid dysgenesis such as osodontoideum, condylustertius, persistent os-terminal, and odontoid aplasia [2].

Acquired anomalies of odontoid may be traumatic, degenerative, inflammatory or neoplastic in nature. Atlanto-axial dislocation and basilar invagination may be seen in both congenital and acquired conditions. Symptoms may refer to the cervical spinal cord, brainstem, cerebellum, cervical nerve roots, lower cranial nerves, and the vascular supply to these structures or the adjacent cerebrospinal fluid channels. Craniocervical junction abnormalities are congenital or acquired abnormalities of the occipital bone, foramen magnum, or first two cervical vertebrae that decrease the space for the lower brain stem and cervical cord [3]. Suspect a craniovertebral junction abnormality if patients have persistentpain in the neck or occiput plus neurologic deficits and symptoms related to the lower brain stem, upper cervical spinal cord or cerebellum. Diagnose craniovertebral abnormalities using MRI or CT of the brain and upper spinal cord. Treatment based on the clinical condition and most of the patients are treated with reduction andimmobilization of compressed neural structures few needs surgery [4].

Materials and Methods

The descriptive study was carried out in the Department of Anatomy, Meenakshi Medical College & Research Institute in collaboration with Department of Radiology (2016-2017), after the institutional ethical committee clearance. The duration of study was one year. Reformatted midline sagittal plain CT images of 150 patients (M-68, F-82) were retrospectively evaluatedin this study. More than 20 years of age with the presentation of specific symptoms were included in this study. The shortest perpendicular distance was measured from the Chamberlain's and McRae's baselines for each subject to the odontoid tip. McRae line is a line drawn on a lateral radiograph of skull connecting the basion and opisthion of the foramen magnum. The tip of the dens should be below the line. Chamberlain line is drawn from the posterior pole of the hard palate to the tip of the opisthion. The tip of the odontoid process should be below the line and not more than 5 mm above it.

CT Position and Analysis

Patients were positioned supine with the orbitalmeatal line perpendicular to the horizontal axis of the table. The head was placed in a cephalstat and secured with forehead band to minimise motion and rotational movements. Three to four millimeters slice thickness noncontrast axial scans of the skull base and upper part of the cervical vertebrae were obtained. Appropriate collimation was done to reduce radiation dose. Measurements were made in accordance with the standard skull-base line definition. The skull-base line points (posterior end of the hard palate, anterior and posterior margin of the foramen magnum) were easily and accurately identified on bone windows CT. The shortest perpendicular distance from each skull-base line to the tip of the odontoid process was measured.

Exclusion Criteria

Head injuries, Klippel-Feil syndrome, odontoid anomalies, or hypoplasia of the atlas, acquired deformity of the skull suggestive of basilar impression development, such as Paget's disease, osteomalacia, rickets, osteogenesis imperfecta, rheumatoid arthritis, neurofibromatosis, and ankylosing spondylitis and a brain tumor or metastatic lesion were excluded from the study.

Statistical Analysis

Results will be expressed as mean±standard deviation and range. Unpaired' test will be used to compare between male and female in CT images. A p-value of 0.05 or less than will be considered for clinical significance.

Results

Out of 150 patients males were (n=68) representing 45.53%. The rest were females (n=82) representing 54.67% of the sample. The age ranged between 21 and 80 years. The mean age of the study patients was 45.5±5.5years; themedian was 50.5 years. In male majority of the patients were in the 41-50 age group (n=23, 33.8%) followed by the 51-60 age group (n= 13, 19.1%). In female majority of the patients were in the 31-40 age group (n=32, 39.02%) followed by the 41-50 age group (n= 20, 24.39%). Female patients were relatively younger compared to the male patients in all the age groups. Simple head trauma and chronic headache were the most common clinical presentation for CT. The mean position of the odontoid process was 2.65 mm below Chamberlain's line (median 2.7 mm, SD 0.21mm) and 4.6 mm (median 4.6 mm, SD 0.19 mm) below McRae's line. There was no statistically significant difference in measurements between male and female patients.

The parameters of both Chamberlain and McRae lines of our study is very close to the Suzgo study and McRae lines is close to CG Cronin study.

Table 1: This table shows our study and compared with the previous studies

SUZGO		CG Cronin		Our Study Outcome	
Position of the odontoid process below the Chamberlain line in mm	Position of the odontoid process below the McRae line in mm	Position of the odontoid process below the Chamberlain line in mm	Position of the odontoid process below the McRae line in mm	Position of the odontoid process below the Chamberlain line in mm	Position of the odontoid process below the McRae line in mm
Mean - 2.6 Median - 2.7	Mean - 4.6 Median -4.7	Mean – 1.4 Median – 1.2	Mean - 5 Median -5	Mean – 2.65 Median - 2.7 8 cases (M-5,F-3) above the line not more than 4.9 mm	Mean– 4.6 Median – 4.6 No cases above the line

Fig. 1: Shows the measurement of chamberlain's line

Fig. 2: Shows the tip of the odontoid process below the chamberlain's line.

Fig. 3: Shows the tip of the odontoid process above the chamberlain's line.

Fig. 4: Shows the measurement of mcrae's line

Fig. 5: Shows the tip of the odontoid process below the mcrae's line

Discussion

The development of odontoid is complex. The top of the dens develops from the proatlas which is cranial half of the first cervical sclerotome. The rest of the dens develops from the caudal half of the first cervical sclerotome. Body and neural arches of the axis develop from the second cervical sclerotome [5]. Proatlas also forms the anterior margin of theforamen magnum, occipital condyles and thethird condyle of the occipital bone similarly caudal portion of the first cervical sclerotome also forms lateral masses and posterior arch of theatlas. Therefore, odontoid dysgenesis is frequently associated with anomalies of basiocciput and atlas [6]. The cruciate and alar ligaments are condensation of the lateral portion of proatlas. A secondary ossification centre appears at the apex (the terminal ossicle) at 3-6 years of age and fuses with the rest of the dens by 12 years of age. Posteriorly, the neural arches fuse by 2-3 years of age. In a young child, the unossified portions of the odontoid may give the false impression of odontoid hypoplasia [7]. Similarly, one may erroneously conclude that the child has C1-2 instability, because the anterior arch of the atlas commonly may slide upward and protrude beyond the ossified portion of the odontoid on the lateral extension radiograph [8]. Evaluating variations between sexes, the findings from this descriptive study and associated literature review provided some useful insights regarding the differences in the relationship of the odontoid tip and skull baselines [9]. The study findings revealed that in males the mean distance from the odontoid tip to Chamberlain's line was 2.54 millimeters (SD 0.19millimeters) and McRae's 4.34 millimeters (SD .17 millimeters).

In female patients, the mean distance from the odontoid tip to Chamberlain's line was 2.76 millimeters (SD 0.23millimeters) and McRae's line was 4.86 millimeters (SD 0.21 millimeters).Using student's t-test there was no significant difference in the distances demonstrated between the two sexes [10]. There were cases in both sexes where the tip of the odontoid was above the lines of Chamberlain's but with no clinical symptoms. This was mostly observed in elderly patients [11]. The maximum asymptomatic distance at which the tip of the odontoid process was above the Chamberlain's was 4.9 millimeters in males and 3.2 millimeters in females. The odontoid tip was never above the McRae's line [12]. CT bone window the clear separation of bone from adjacent soft tissues and the capabilities to easily obtain a midsagittal reconstructed image resulted in more accurate measurements [13]. The findings of the study demonstrated that there was a decrease in the distance from the tip of the odontoid process to skull baselines of Chamberlain's and McRae's with advancing age and in some cases the odontoid tip was above the skull baselines with no clinical symptoms. [14,15]. A possible explanation for these findings is that with age, bone and adjacent soft tissue undergo involution. Bone demineralization (osteomalacia) due to age predisposes to bone deformities. Associated ligament laxity may lead to joint subluxation resulting in theupward migration of the odontoid tip [15,16]. Though there was a notable difference in the distance from the odontoid tip to skull baselines with age in our current study, statistical correlation of the findings demonstrated no significant difference (p-value < 0.05)[17].

Conclusion

The Odontoid process is affected by a variety of congenital and acquired diseases. Imaging of this small structure to reach a specific diagnosis continues to be a challenge for radiologists. Multiplanar imaging with CT allows more detailed evaluation of bony and soft tissue structures. Adequate knowledge of development, complex anatomy, various disease processes, topographic relationships of odontoid with respect to CVJ and craniometry in association with theappropriate clinical background can provide ameaningful diagnosis. The distances of the odontoid tip to the skull baselines of Chamberlain's and McRae's were noted to be higher in males than females. The difference seen was however not statistically significant. The study revealed that the distance of the odontoid tip to standard skull baselines was reducing with age. Resorbtive bone changes of the elderly and laxity of ligaments supporting the odontoid process were possible explanations. Bony landmarks were clearly identified and the measuring techniques were easily demonstrated in this study using multiplanar CT. These results provide the mean of normal distance from the odontoid process to the standard skull base lines on CT. This study can be used as a base line data to access skull base problems.

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